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Myocardial Imaging
Tissue Doppler and Strain Imaging

Steven J. Lester MD, FRCP(C), FACC, FASE

DISCLOSURE

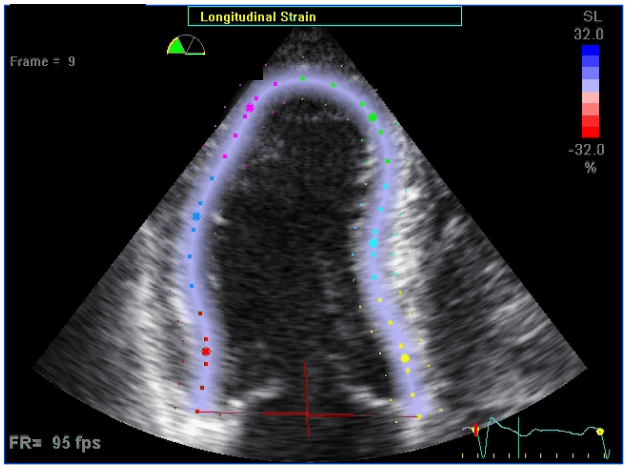
Relevant Financial Relationship(s)

None

Off Label Usage

None

Myocardial Imaging



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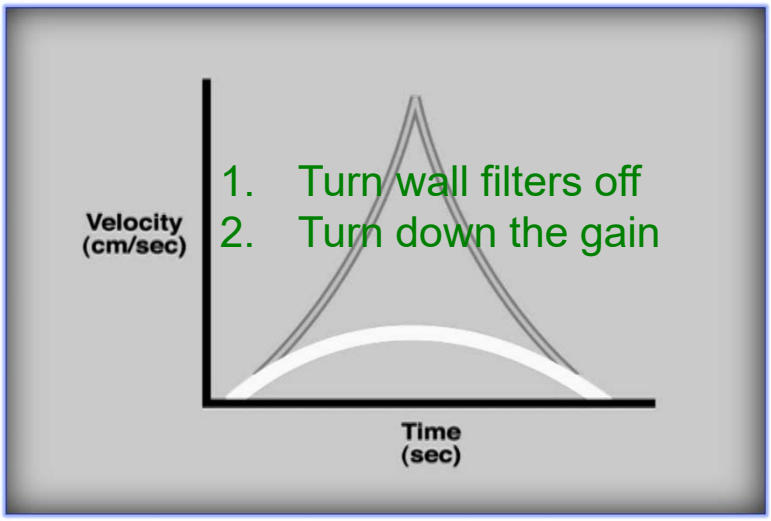
Doppler:
Doppler Tissue Imaging



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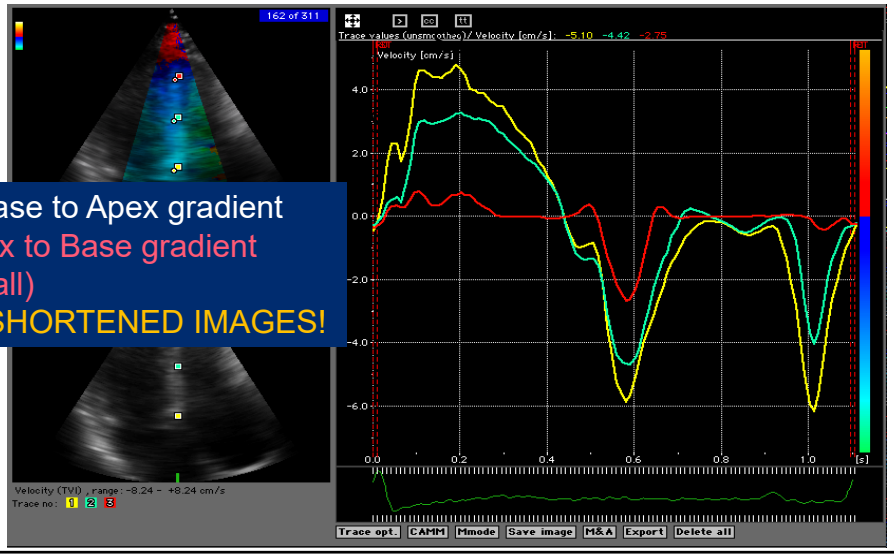
Doppler Tissue Imaging

Septal Myocardial Velocity Traces



Velocity: Base to Apex gradient
Strain: Apex to Base gradient (small)
FORESHORTENED IMAGES!

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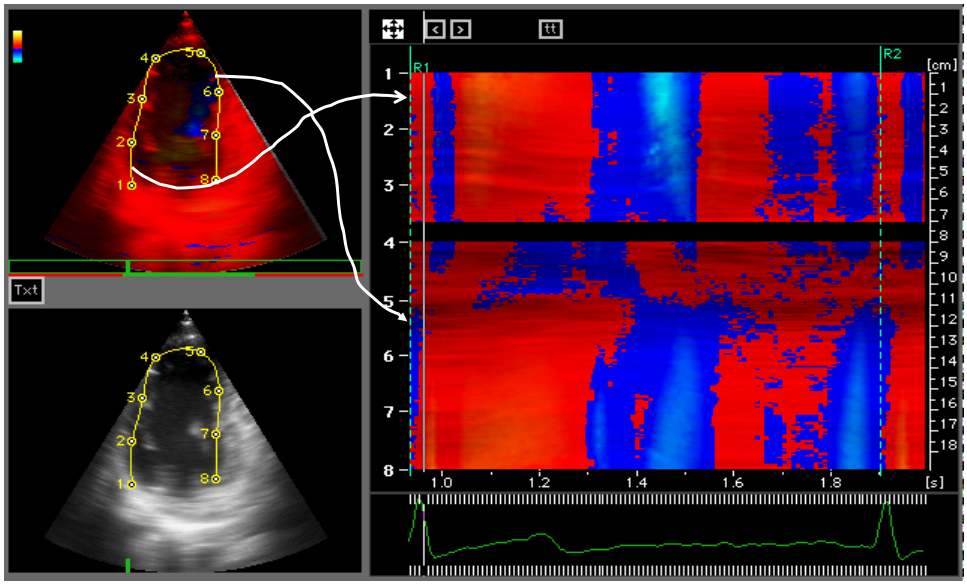
Curved M-mode : DTI



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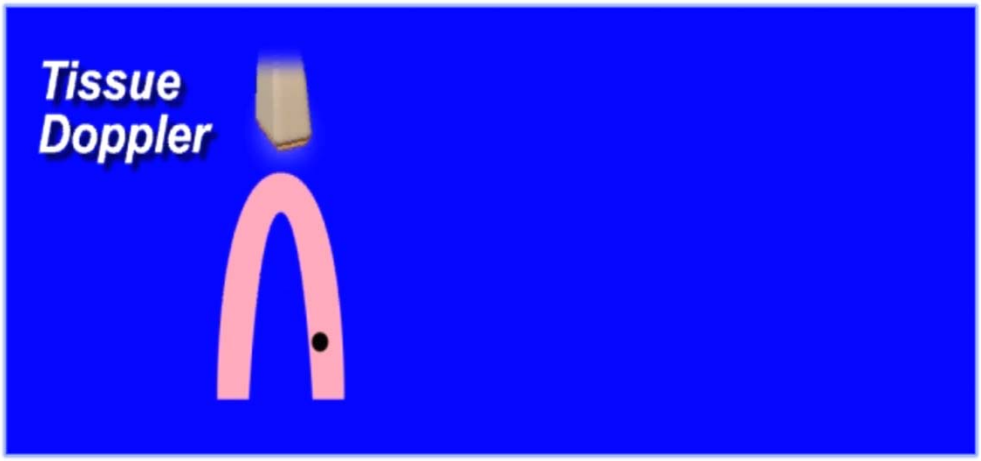
Goal

To Detect Regional Wall Motion



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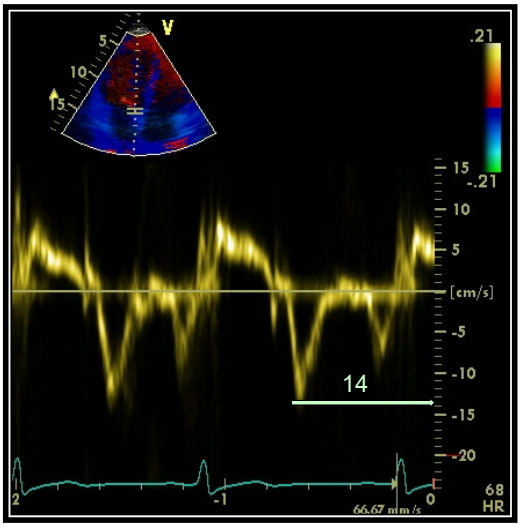
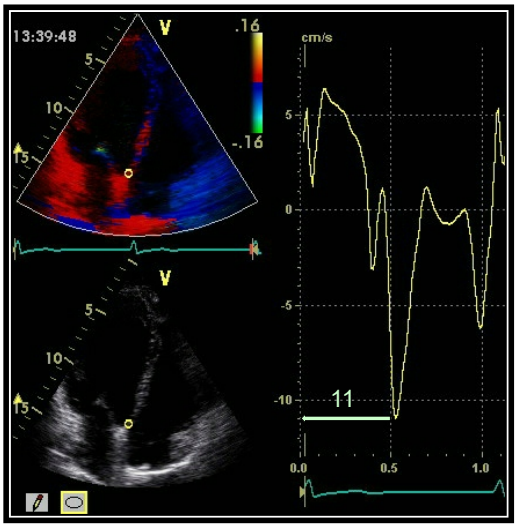
Pulsed TD
Peak Velocities



Color TD
Mean Velocities



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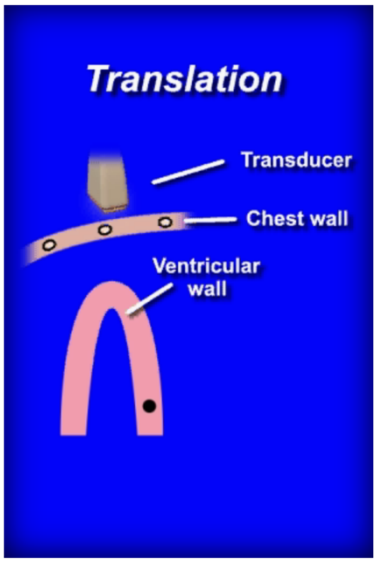
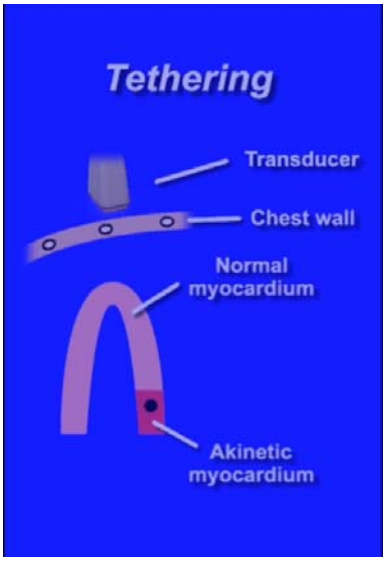
Pitfall (Velocity Analysis)

Translation and Tethering





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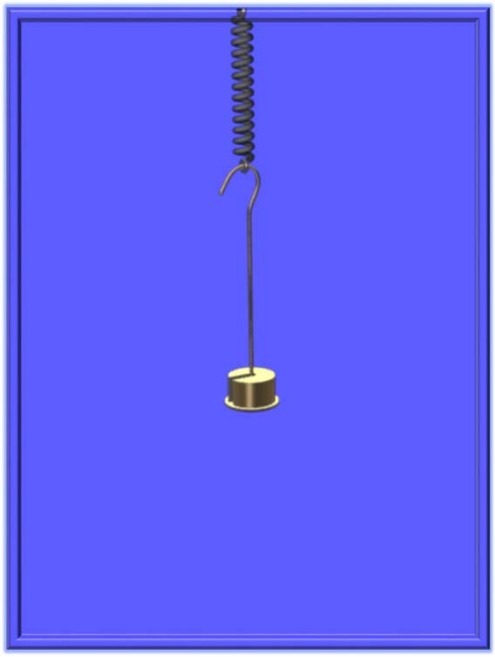

Strain = deformation resulting from applied force

Stress = force

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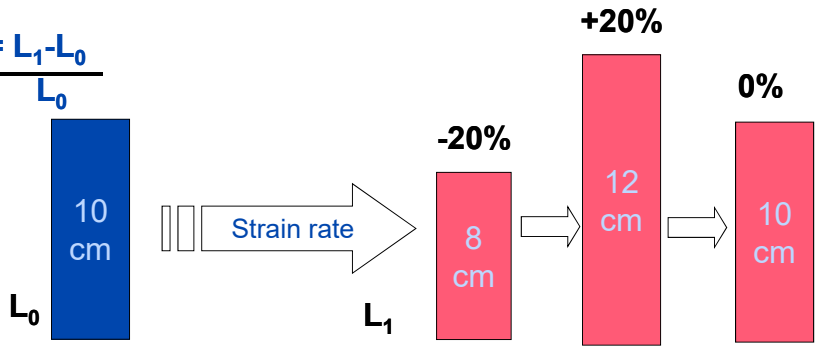
Courtesy of Ted Abraham

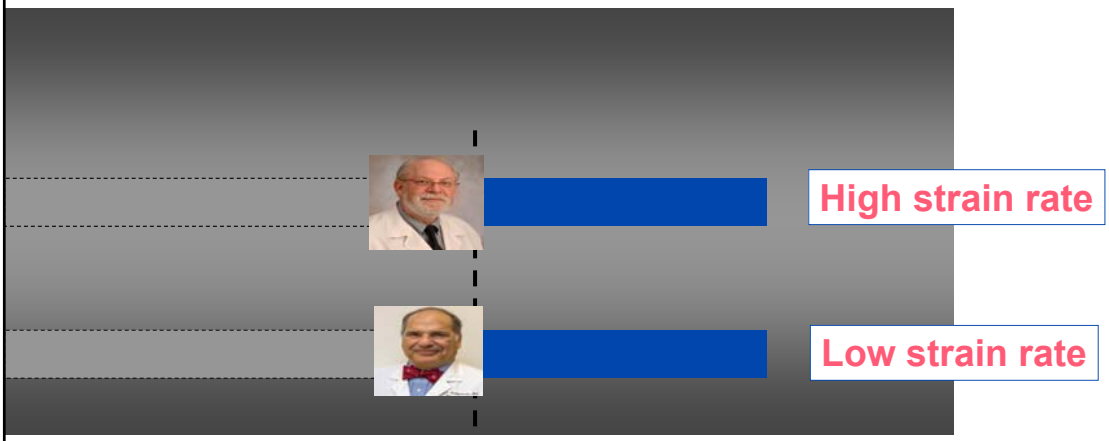
Myocardial strain

Used to describe elastic properties of cardiac muscle (Mirsky and Parmley: Circ Res, 1973)

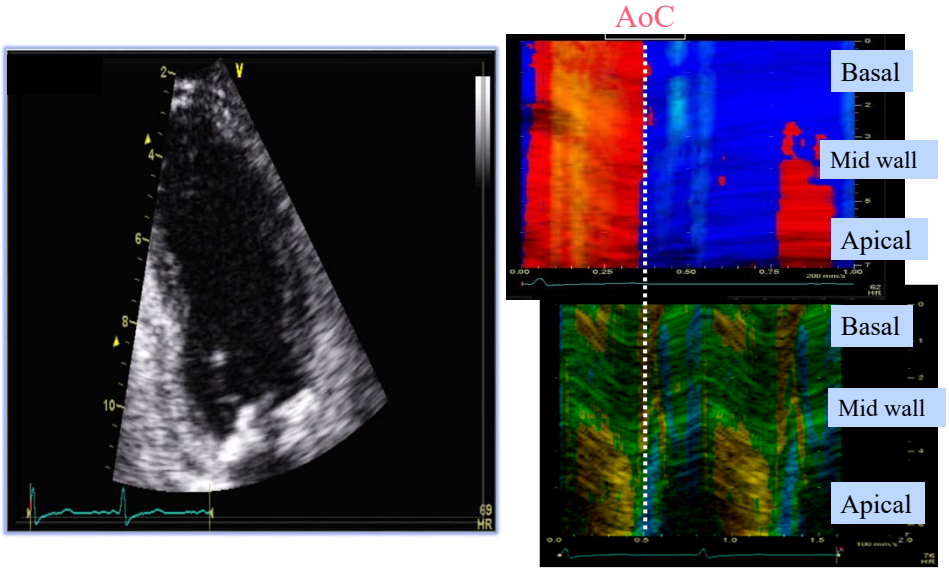
$$\text{Strain } (\varepsilon) = \frac{L_1 - L_0}{L_0}$$



Strain rate: Rate of deformation

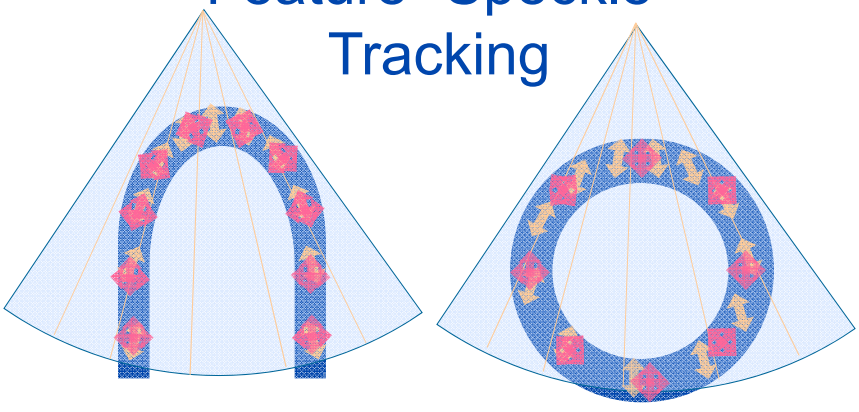


Strain rate vs. Tissue Doppler



Doppler

Feature "Speckle" Tracking

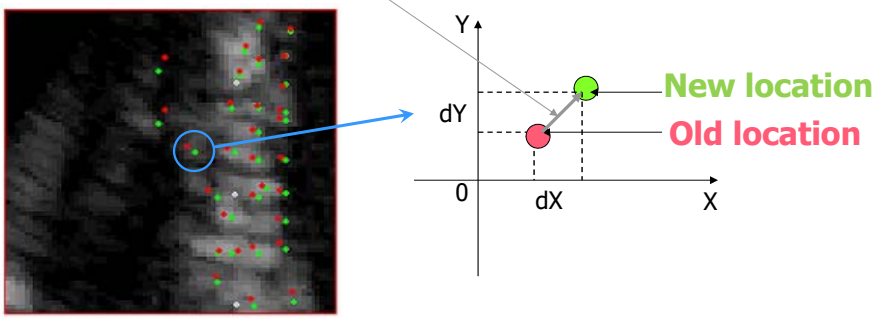


Movement of the myocardium relative to the sample volume fixed in space

Acoustic pattern tracking
Speckle Tracking

Velocity is estimated as a shift of each object divided by time between successive frames (or multiplied by Frame Rate)-->

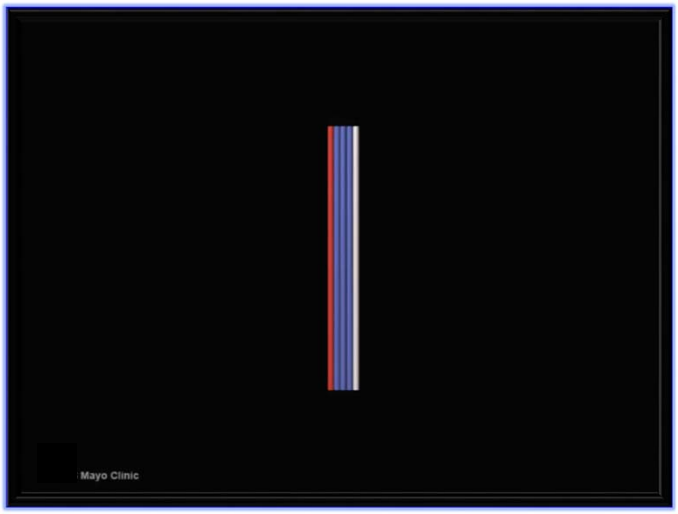
2D vector: (Vx, Vy) = (dX, dY) * FR



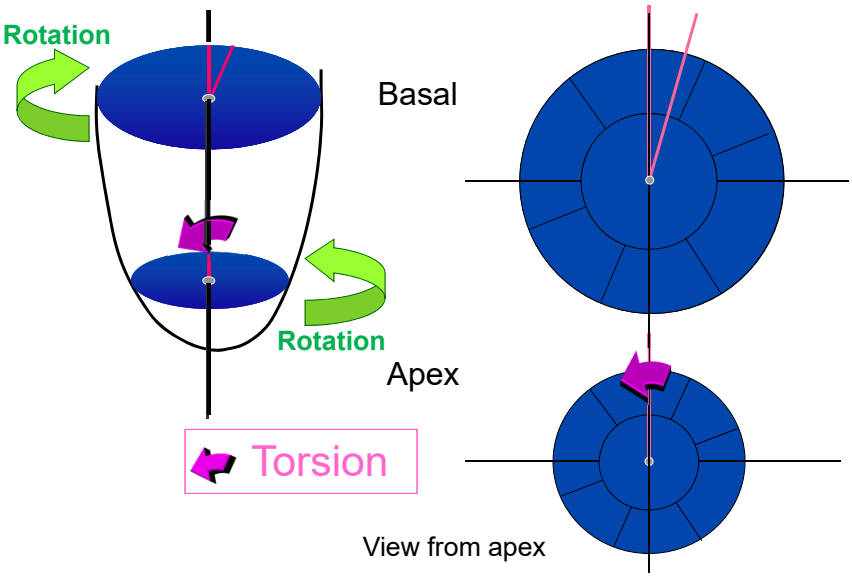
Doppler Independent Techniques (Speckle Tracking)
Potential Advantage?

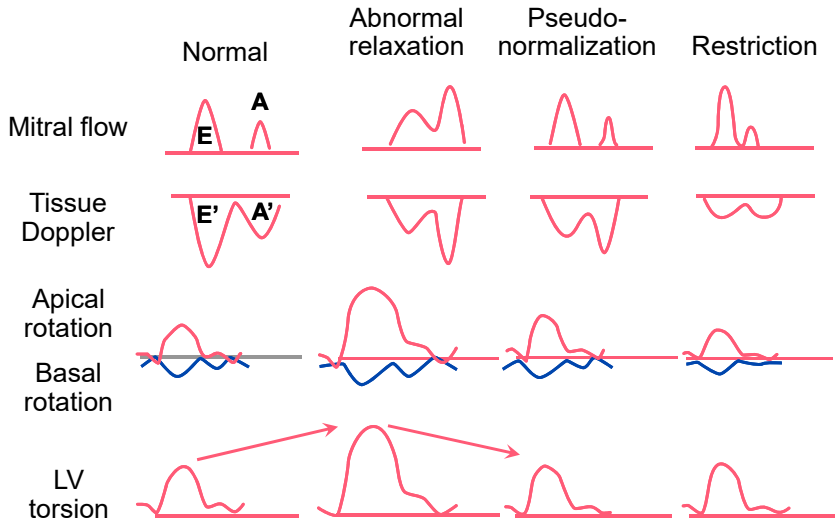
- Signal noise
- Speckle tracking by principle is angle independent
- Gray scale (standard views)
- Monitor strain in two rather than one dimension
- Minimal user input
- Assessment of rotation: derived from circumferential strain at different levels in the heart (NO fixed sample volume)

Myocardial Mechanics
Rotation/Twist/Torsion

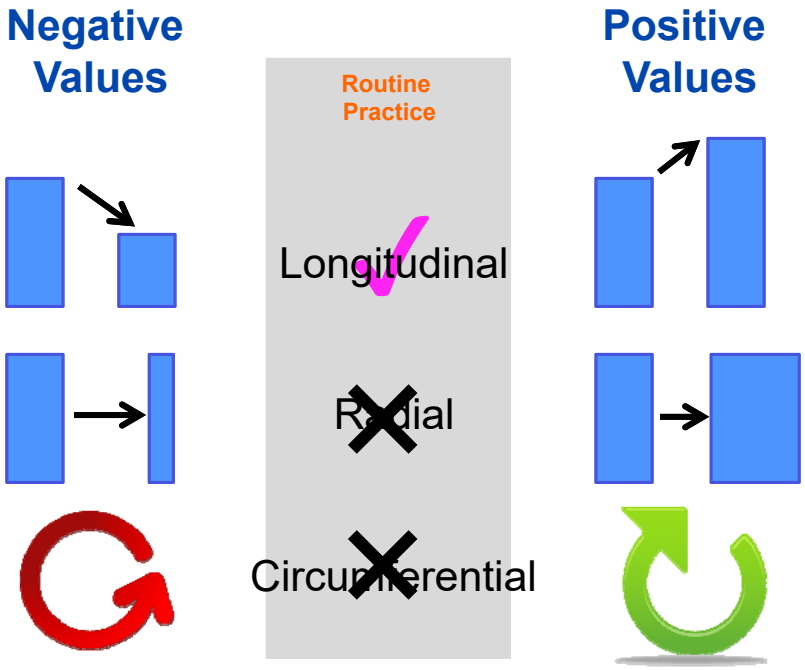


Rotation and Torsion





Park et al: J Am Soc Echo Cardiogr 21:1129, 2008



Global Longitudinal Peak Systolic Strain

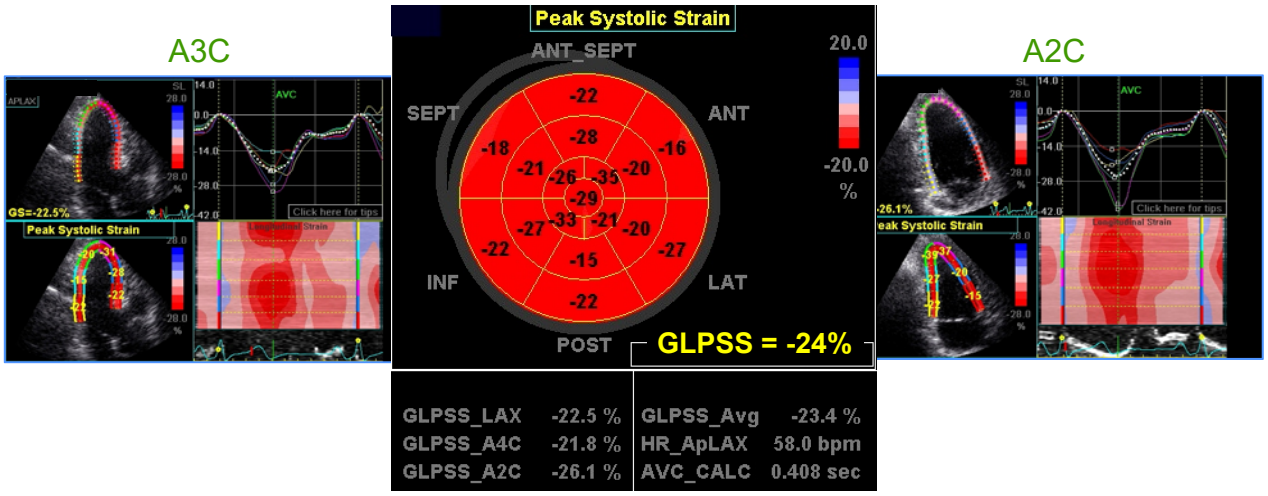
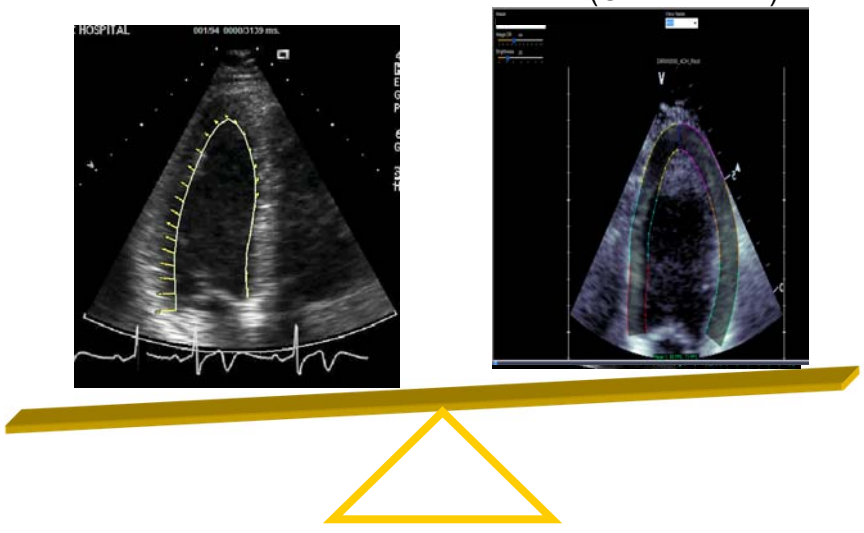


Image Arena 2D Speckle Tracking

(GE Vivid™ 7)



Echocardiographic Measures of Myocardial Deformation by Speckle-Tracking Technologies: The Need for Standardization?

Matthew R. Nelson, MD, R. Todd Hurst, MD, Serageldin F. Raslan, MD, Stephen Cha, MS, Susan Wilansky, MD, and Steven J. Lester, MD, *Scottsdale, Arizona; Rochester, Minnesota*

Echocardiographic Measures of Myocardial Deformation by Speckle-Tracking Technologies: The Need for Standardization?

than two left ventricular endocardial segments poorly delineated were excluded. GLS was obtained from the apical four-chamber, three-chamber, and two-chamber views using two independent speckle-tracking echocardiographic software packages (EchoInsight version 1.5.0 and Image-Arena version 4.5). Linear regression analysis and paired *t* tests were used to compare GLS results. Intraclass correlation coefficients and Bland-Altman plots were used for assessments of reliability.

Results: The "out-of-the-box" mean GLS was −12.99 ± 2.38% using EchoInsight and −16.87 ± 2.84% using Image-Arena (mean difference, 3.87 ± 2.42%; $P = .0001$). Agreement between the software packages was moderate (intraclass correlation coefficient, 0.43; 95% confidence interval, 0.32–0.55). Using uniform variables to derive GLS (Lagrangian strain measured in systole and diastole at the endocardium and averaging the peak segmental

J Am Soc Echocardiogr 2012:25:1189-94

% (mean differval, 0.52–0.79).

Conclusions: Image-Arena GLS results were consistently different (more negative) than EchoInsight measures out of the box but became similar when information used to derive GLS was uniform. The evolution of measures of myocardial mechanics into routine clinical practice will require vigilance and standardization of the various techniques, necessitating independent validation of commercially available speckle-tracking echocardiographic products. (J Am Soc Echocardiogr 2012;25:1189-94.)

Keywords: Speckle-tracking, Strain, Echocardiography

REPRODUCIBILITY OF LEFT VENTRICULAR STRAIN

Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors

The EACVI/ASE Inter-Vendor Comparison Study

Konstantinos E. Farsalinos, MD, Ana M. Daraban, MD, Serkan Ünlü, MD, James D. Thomas, MD, Luigi P. Badano, MD, PhD, and Jens-Uwe Voigt, MD, PhD, *Leuven, Belgium; Chicago, Illinois; and Padua, Italy*

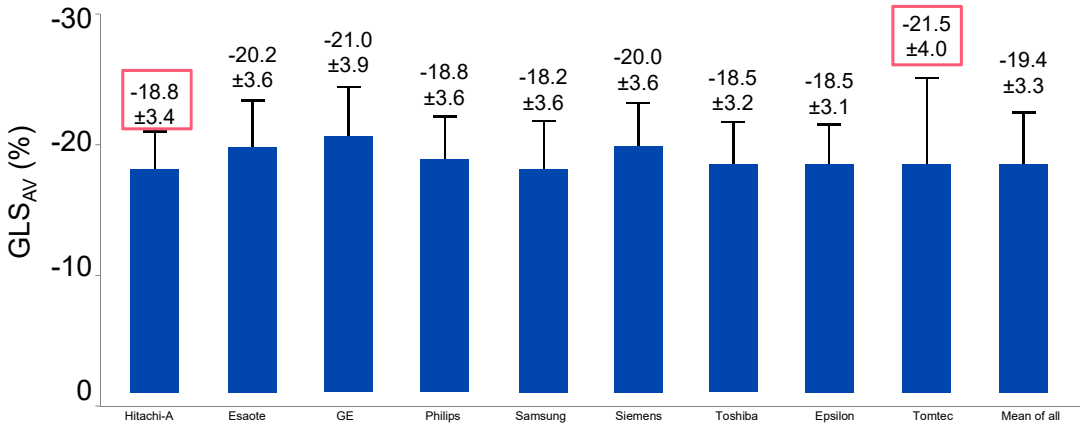
Background: This study was planned by the EACVI/ASE/Industry Task Force to Standardize Deformation Imaging to (1) test the variability of speckle-tracking global longitudinal strain (GLS) measurements among different vendors and (2) compare GLS measurement variability with conventional echocardiographic parameters.

Methods: Sixty-two volunteers were studied using ultrasound systems from seven manufacturers. Each volunteer was examined by the same sonographer on all machines. Inter- and intraobserver variability was determined in a true test-retest setting. Conventional echocardiographic parameters were acquired for comparison. Using the software packages of the respective manufacturer and of two software-only vendors, endocardial GLS was measured because it was the only GLS parameter that could be provided by all manufactures. We compared GLS_{AV} (the average from the three apical views) and GLS_{4CH} (measured in the four-chamber view) measurements among vendors and with the conventional echocardiographic parameters.

Results: Absolute values of GLS_{AV} ranged from 18.0% to 21.5%, while GLS_{4CH} ranged from 17.9% to 21.4%. The absolute difference between vendors for GLS_{AV} was up to 3.7% strain units ($P < .001$). The interobserver relative mean errors were 5.4% to 8.6% for GLS_{AV} and 6.2% to 11.0% for GLS_{4CH}, while the intraobserver relative mean errors were 4.9% to 7.3% and 7.2% to 11.3%, respectively. These errors were lower than for left ventricular ejection fraction and most other conventional echocardiographic parameters.

Conclusion: Reproducibility of GLS measurements was good and in many cases superior to conventional echocardiographic measurements. The small but statistically significant variation among vendors should be considered in performing serial studies and reflects a reference point for ongoing standardization efforts. (J Am Soc Echocardiogr 2015;28:1171-81.)

Global Longitudinal Strain Among Various Vendors



Farsalinos et al: J Am Soc Echocardiogr 28:1171, 2015

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber

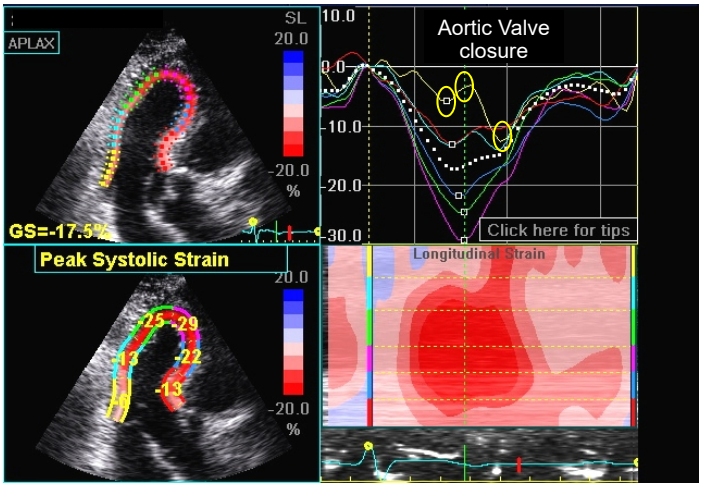
Global Longitudinal Peak Systolic Strain (GLS) "in the range of -20%"

- "Optimize image quality, maximize frame rate and minimize foreshortening".
- "When regional tracking is suboptimal in more than two myocardial segments in a single view the calculation of GLS should be avoided".

assembled by the American Society of Echocardiography and the European Association of Cardiovascular Imaging. This document provides updated normal values for all four cardiac chambers, including three-dimensional echocardiography and myocardial deformation, when possible, on the basis of considerably larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

Timing: End-Systole?



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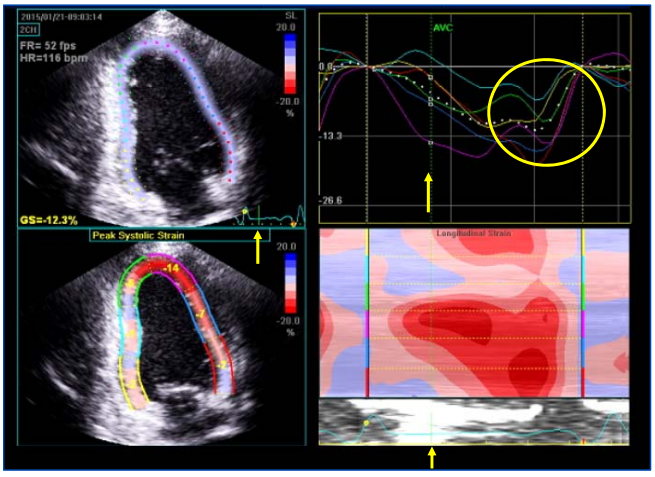
Timing: End-Systole?



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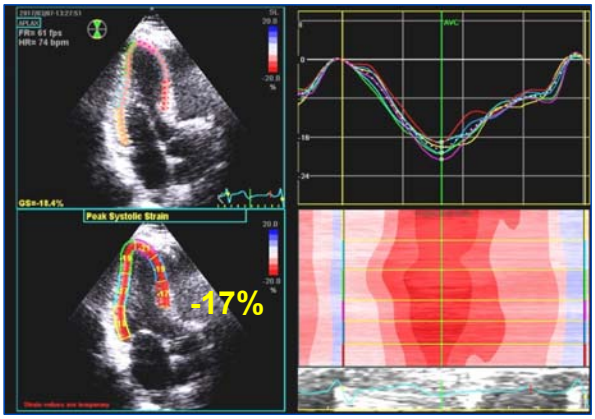
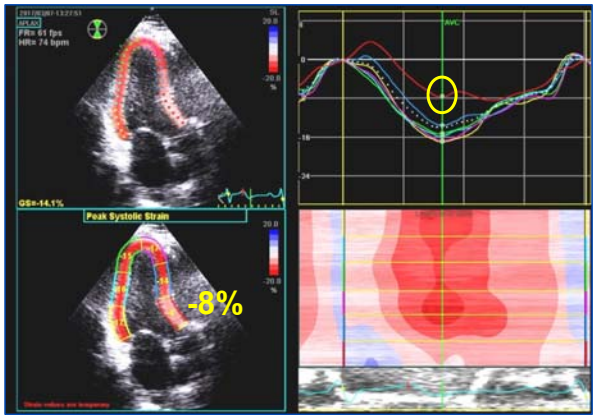
Pitfall: Avoid The LVOT

Good



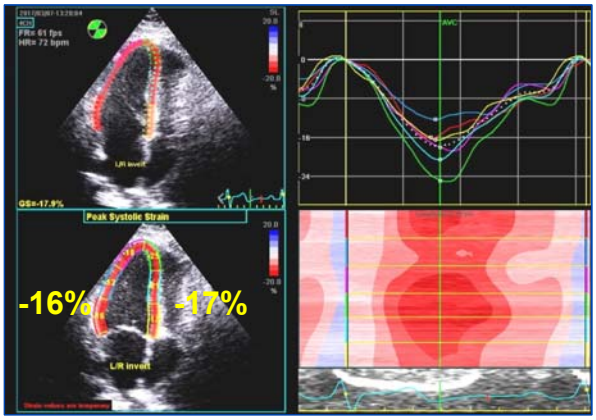
Bad



MAYO CLINIC

Pitfall: Avoid The Atrium

Good



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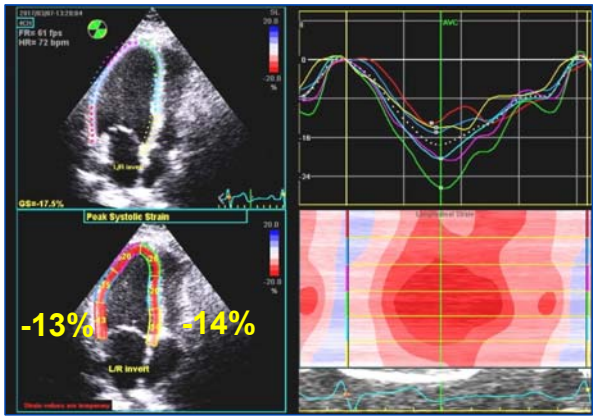

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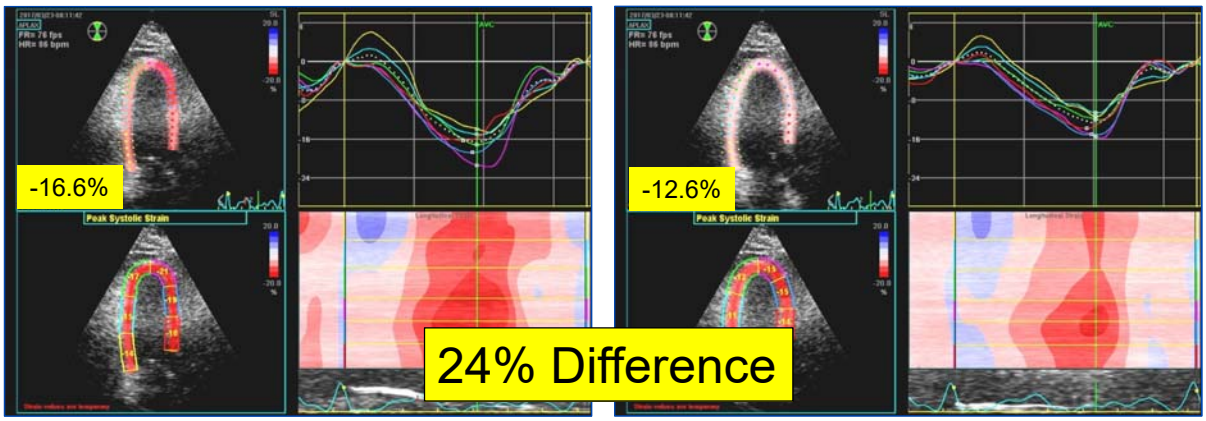
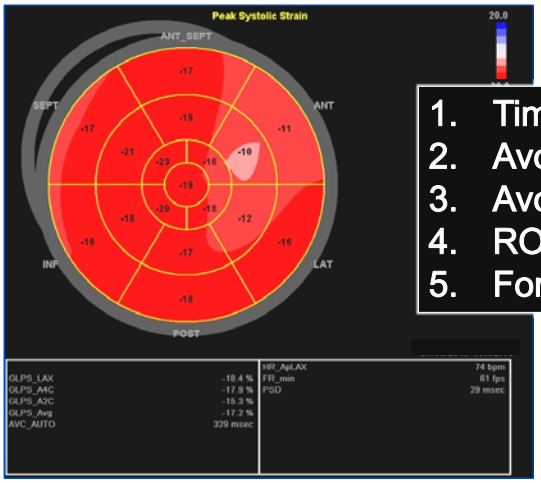
Pitfall: ROI To Wide

Good **Bad**

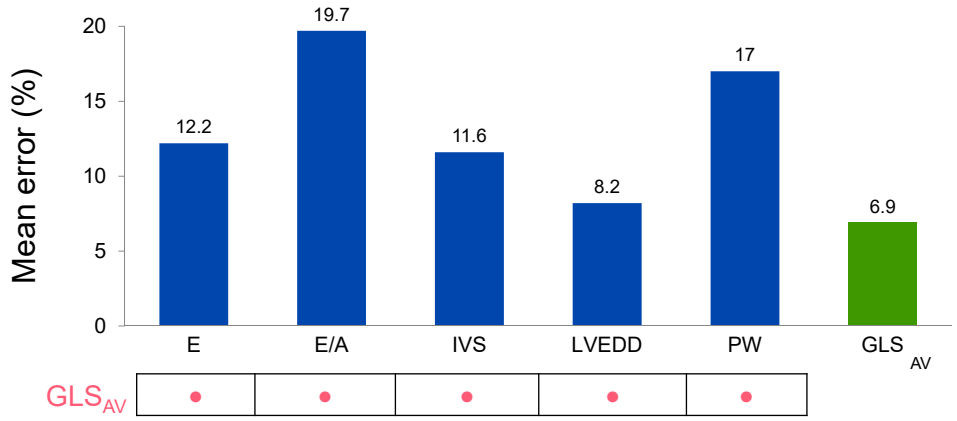


Global Longitudinal Peak Systolic Strain



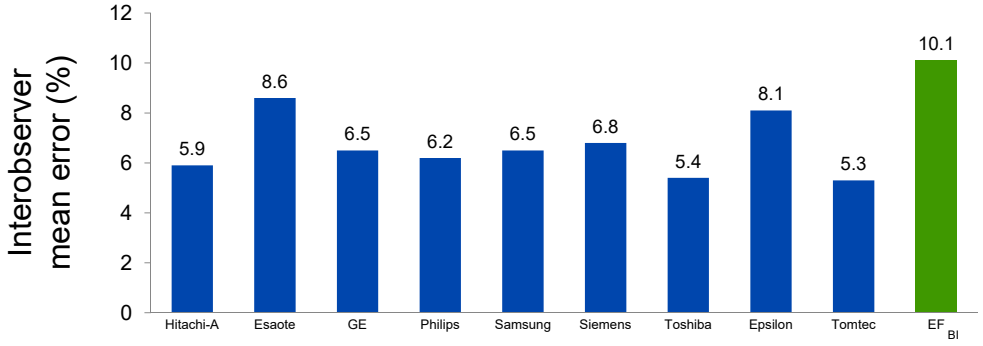
1. Timing of Aortic Valve Closure
2. Avoid LVOT
3. Avoid the Atrium
4. ROI to Wide
5. Foreshortened Images

Mean Error in Measurements



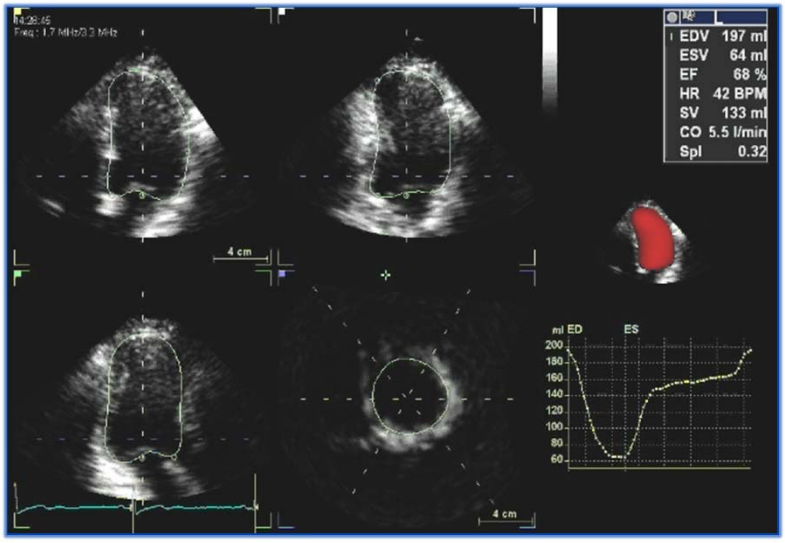
Farsalinos et al: J Am Soc Echocardiogr 28:1171, 2015

Interobserver Relative Mean Errors



Farsalinos et al: J Am Soc Echocardiogr 28:1171, 2015

3D LV Volumes and Ejection Fraction



Reproducibility of Echocardiographic Techniques for Sequential Assessment of Left Ventricular Ejection Fraction and Volumes

Application to Patients Undergoing Cancer Chemotherapy

Paaladinesh Thavendiranathan, MD, MSc, Andrew D. Grant, MD, Tomoko Negishi, MD, Juan Carlos Plana, MD, Zoran B. Popović, MD, PhD, Thomas H. Marwick, MD, PhD, MPH
Cleveland, Ohio

"Our data suggest that the temporal variability in EF of **0.06** might occur with noncontrast 3DE due to physiological differences and measurement variability, whereas this might be **>0.10** with 2D methods. Overall, 3DE also had the best intra- and inter-observer as well as test-retest variability"

triplane, and 3-dimensional echocardiography (3DE) by 2 investigators blinded to any clinical data. Inter-, intra-, and test-retest variability were assessed in a subgroup. Variability was assessed by analysis of variance and compared with Levene's or *t* test.

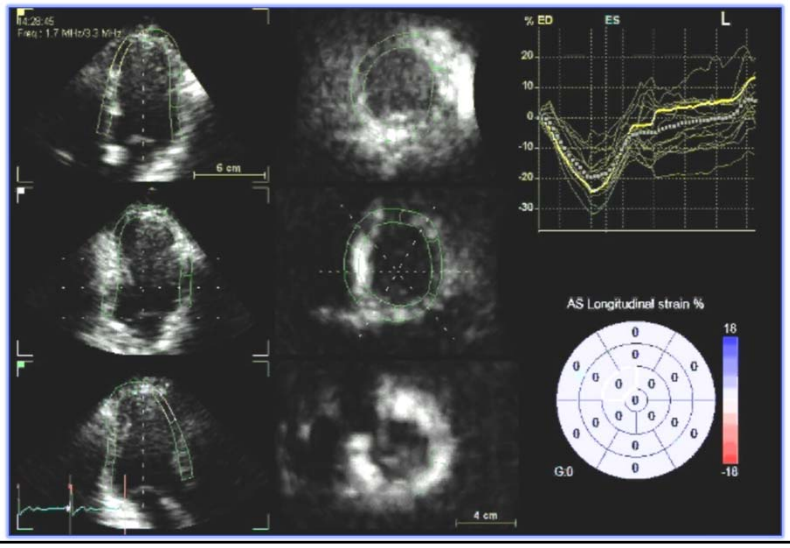
Results Among 56 patients (all female, 54 ± 13 years of age), noncontrast 3D EF, end-diastolic volume, and end-systolic volume had significantly
temporal variability of LV end-di
a temporal variability in EF of 0.0
surement variability, whereas thi
inter-observer as well as test-retest variability.

Conclusions Noncontrast 3DE was the most reproducible technique for LVEF and LV volume measurements over 1 year of follow-up. (J Am Coll Cardiol 2013;61:77–84)

J Am Coll Cardiol 2013;61:77-84

3D Strain Analysis

Lower resolution
(spatial and temporal)



Potential Clinical Applications

Cardio-Oncology

At The Heart Of Cancer

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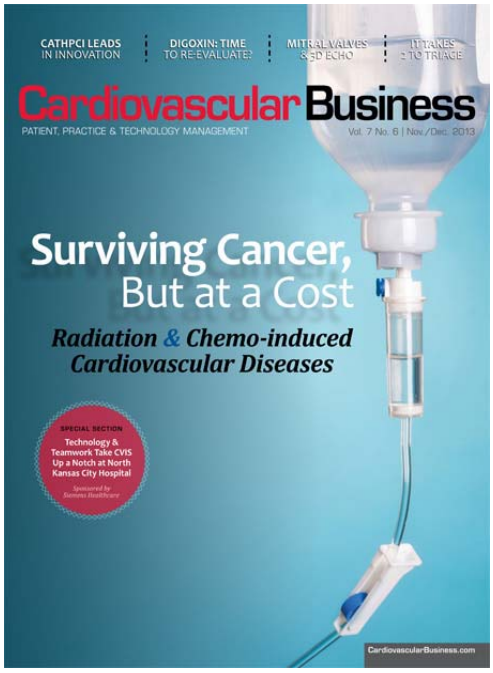
Case

- 59-year-old male
- Acute Myeloid Leukemia
- No prior history of vascular disease.
- Hypertension treated with Amlodipine.
- About to begin chemotherapy based treatment

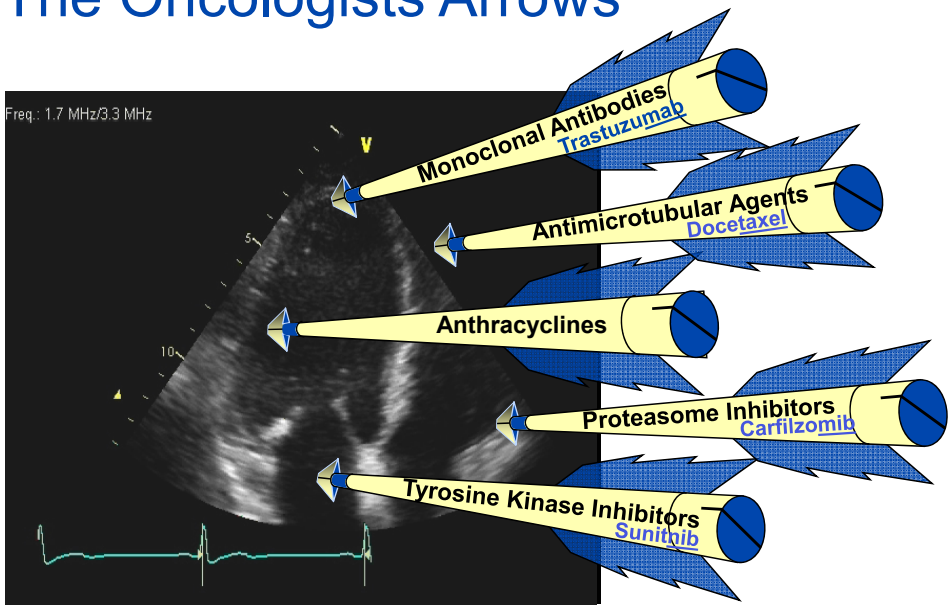
MAYO CLINIC



Oncologist
"Killer"

Cardiologist
"Protector"

The Oncologists Arrows

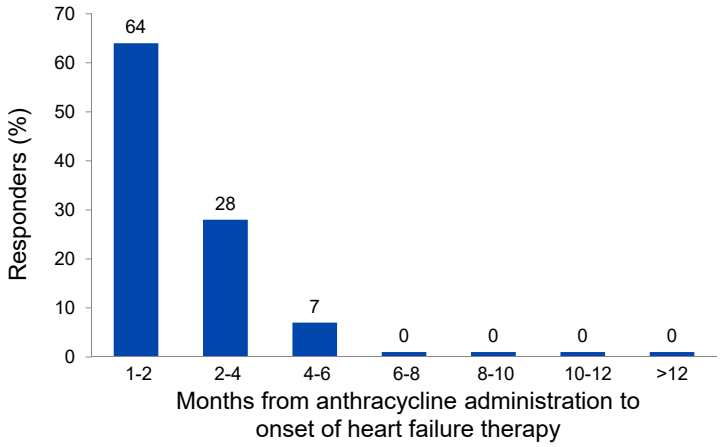


Niccolo Machiavelli (1469-1527)

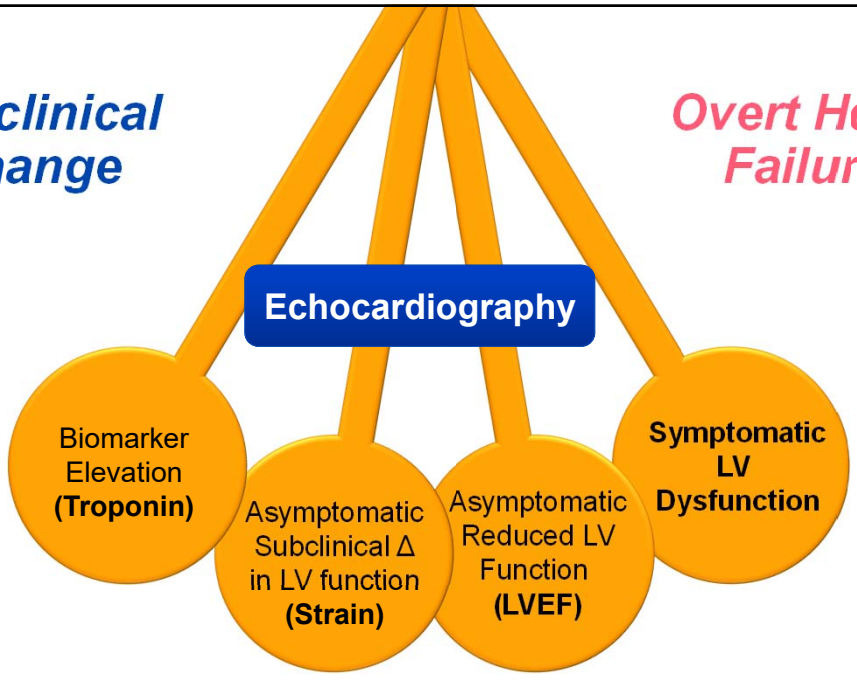
"…at the beginning a disease is ***easy to cure but difficult to diagnose***; but as time passes, not having been recognized or treated at the outset, ***it becomes easy to diagnose but difficult to cure***."

Percentage of Responders To Heart Failure Therapies

ACEI & Beta Blockers



Cardinale et al: J Am Coll Cardiol 55:213, 2010

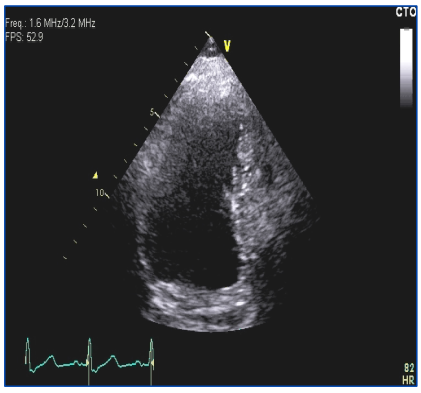


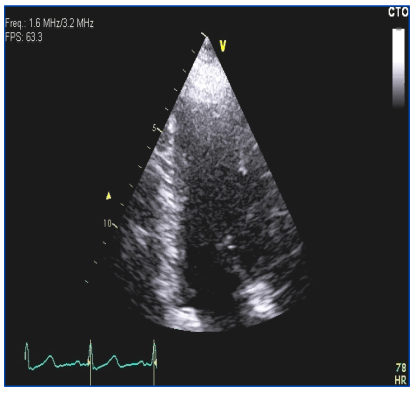
Case

- 59-year-old male
- Acute Myeloid Leukemia
- No prior history of vascular disease.
- Hypertension treated with Amlodipine.
- About to begin chemotherapy based treatment

Baseline Echocardiogram

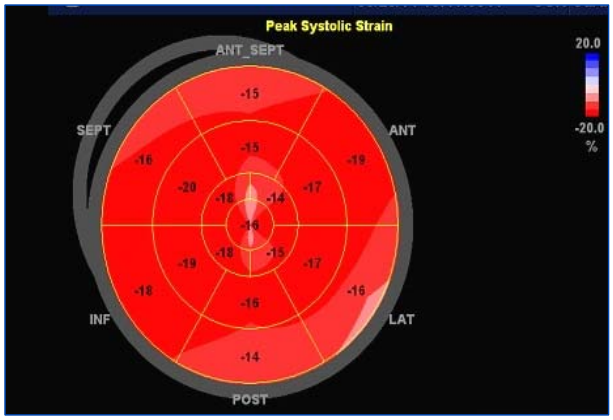
LVEF = 66%, EDVI = 53 ml/m^2





Baseline Echocardiogram
Global Longitudinal Peak Systolic Strain

LVEF = 66% GLS Avg = -17.3%



EXPERT CONSENSUS STATEMENT

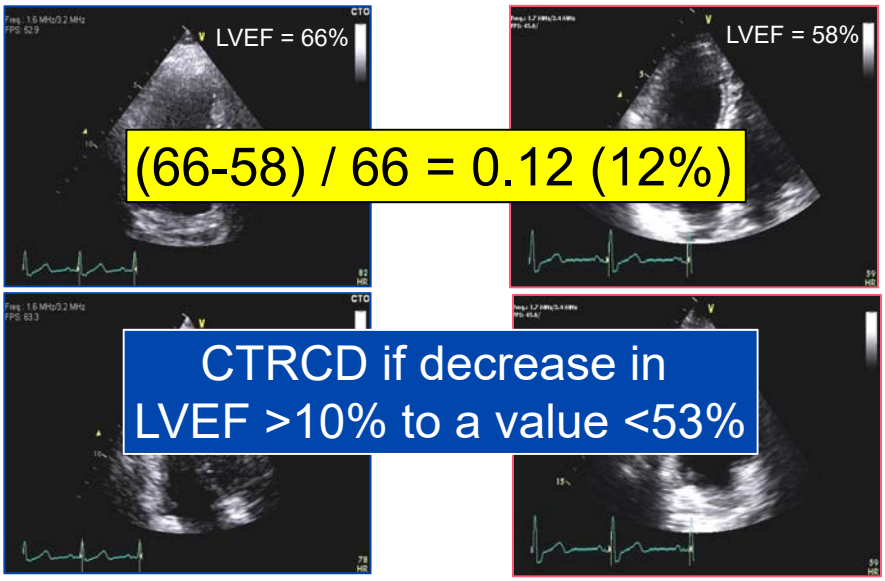
Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy: A Report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

1. **CTRCD if decrease in LVEF >10% to a value <53%**
2. **In patients with available baseline strain measurements, a relative percentage reduction of GLS of <8% from baseline appears not to be meaningful, and those >15% from baseline are very likely to be abnormal.**

(J Am Soc Echocardiogr 2014;27:911-39.)

Baseline

2 Months



(66-58) / 66 = 0.12 (12%)

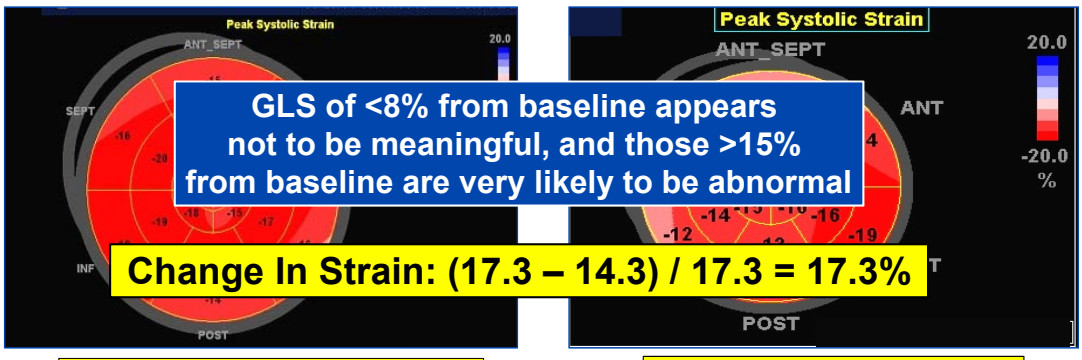
CTRCD if decrease in LVEF >10% to a value <53%

Baseline

2 Months

LVEF = 66%

LVEF = 58%



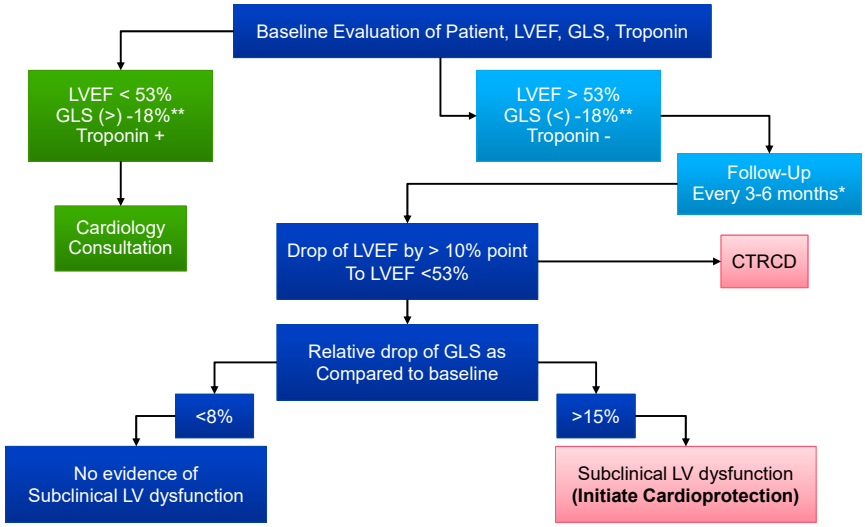
GLS of <8% from baseline appears not to be meaningful, and those >15% from baseline are very likely to be abnormal

Change In Strain: (17.3 – 14.3) / 17.3 = 17.3%

GLPSS Avg = -17.3%
Troponin T = 0.02

GLPSS Avg = -14.3%
Troponin T = **0.03**

Cardio-Oncology Screening Strategy



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Case

- 64 year old woman
- HER2 positive infiltrating lobular carcinoma of the right breast
- HER2 positive ductal carcinoma insitu of the left breast.
- Preoperative chemotherapy with paclitaxel (80mg/m^2) and trastuzumab. Paclitaxel discontinued after 8 infusions due to toxicity (neuropathy).
- Then preoperatively started Q3weekly doxorubicin/cyclophosphamide (discontinued after 2 cycles due fatigue and anorexia).

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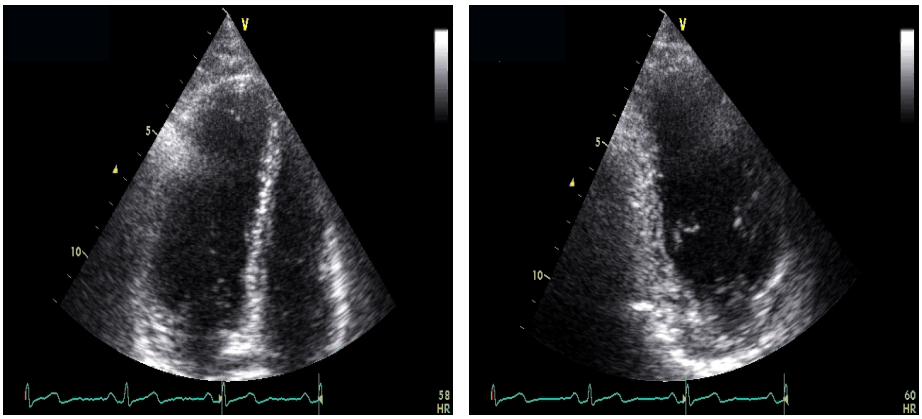
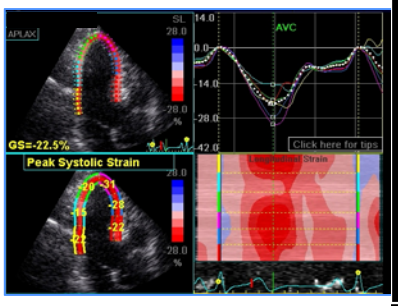
Pre-Treatment Echocardiogram

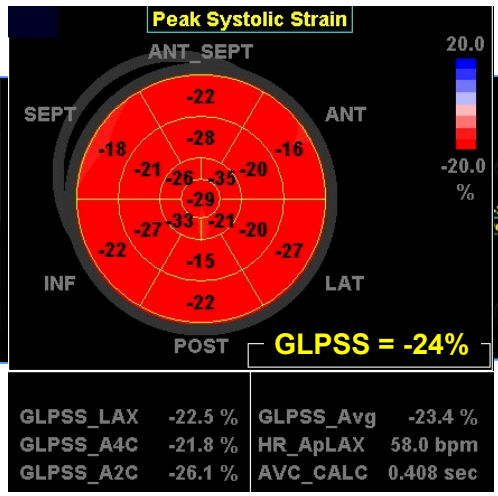
LVEF = 65%



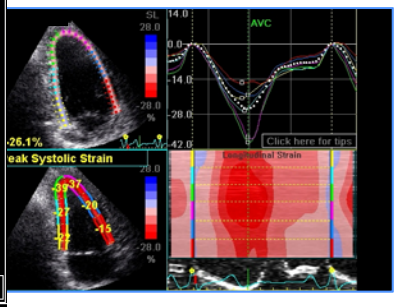
Pre-Treatment: Strain Imaging

A3C



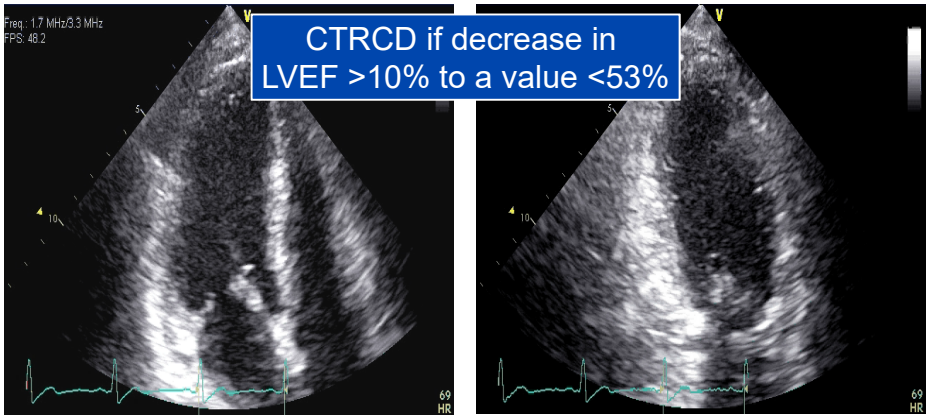


A2C



3 Months Into Treatment Echocardiogram

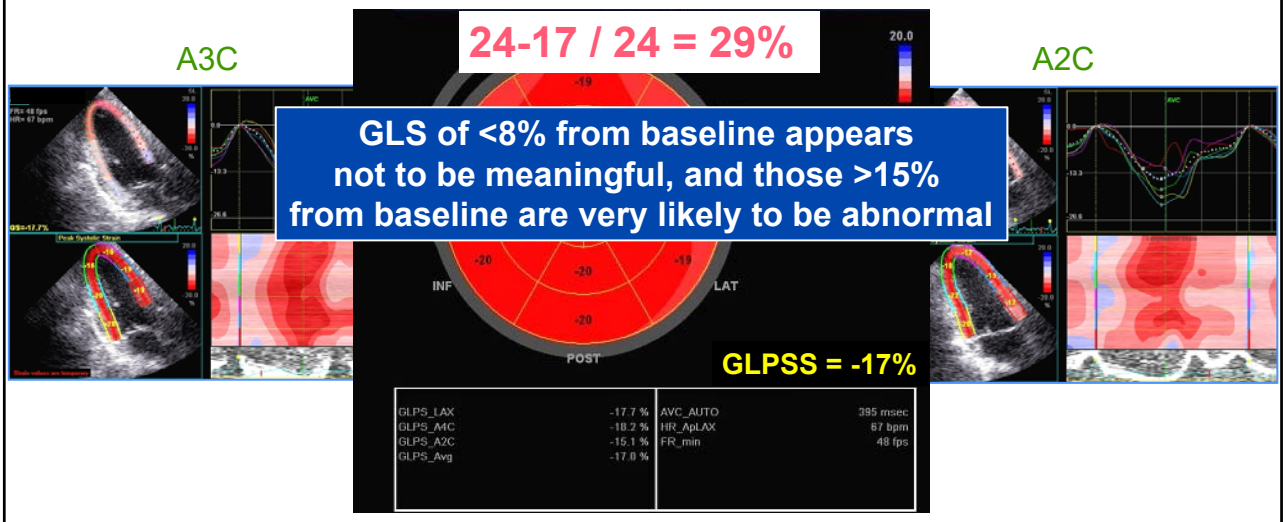
LVEF = 65-59/65 = 9%



3 Months Into Treatment: Strain Imaging

A3C

A2C



What should we do now?

- LVEF dropped from 65% to 59% (9% RRR)
- GLPSS dropped from -24% to -17% (29% RRR)
- Started treatment with Coreg and Enalapril
- Initiated adjuvant trastuzumab and anastrozole
- Serial echocardiograms Q2-3 months

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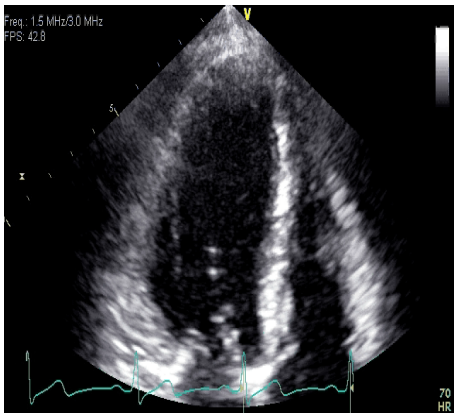
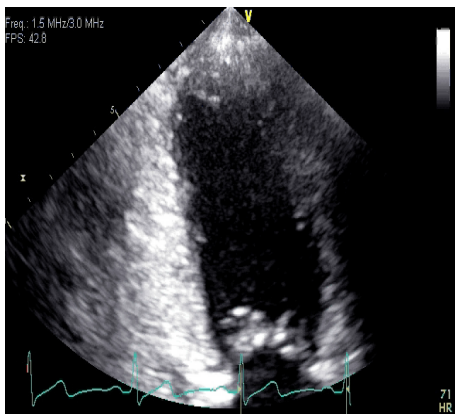
Completion of 1 year of adjuvant trastuzumab

LVEF = 59%





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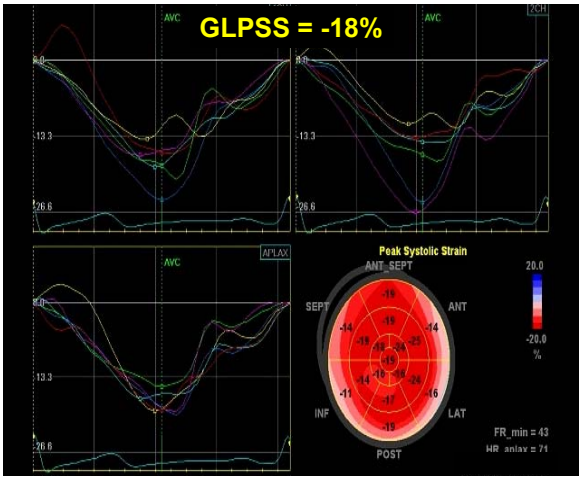
Completion of 1 year of adjuvant trastuzumab



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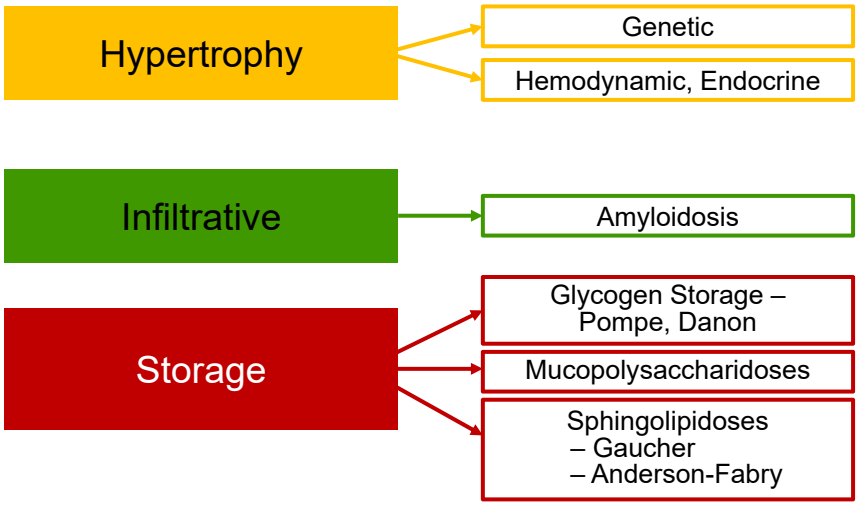
Thick Walls Why?



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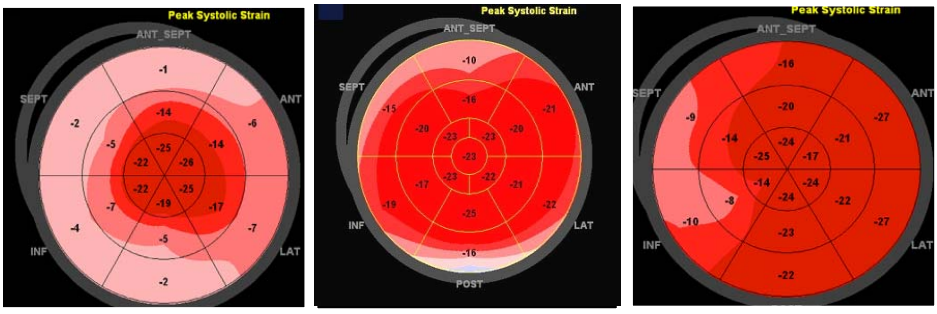
Are They Really The Same?

Cardiac Amyloidosis | Hypertensive Heart Disease | Hypertrophic Cardiomyopathy



14mm | 14mm | 13mm

Mean Wall Left Ventricular Thickness

Pattern Recognition

LV Mechanics in Mitral and Aortic Valve Diseases

Value of Functional Assessment Beyond Ejection Fraction

Elena Galli, MD, PhD,* Patrizio Lancellotti, MD, PhD,† Partho P. Sengupta, MD, DM,‡ Erwan Donal, MD, PhD*

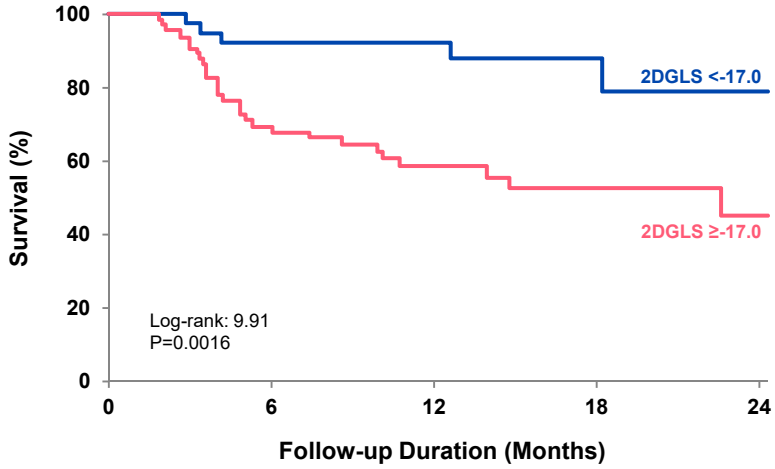
ABSTRACT

- "LV dysfunction is frequently subclinical despite a normal ejection fraction. It may preceded the onset of symptoms and portend a poor outcome…"
- "The advent of novel tissue-tracking echo techniques has unleashed new opportunities for the clinical identification of early abnormalities in LV function".

regarding the use of these techniques to assess myocardial deformation in patients with valvular heart disease. (J Am Coll Cardiol Img 2014;7:1151-66) © 2014 by the American College of Cardiology Foundation.

Asymptomatic Severe Aortic Stenosis and LVEF ≥ 50%

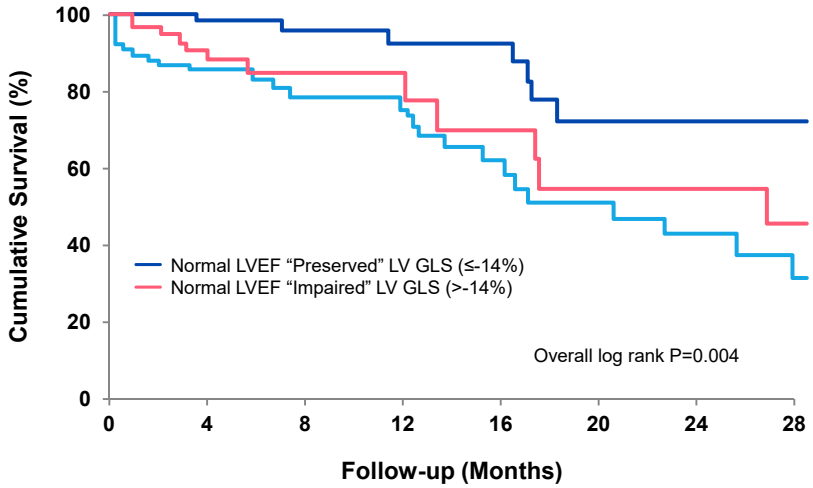
Survival from MACE



Nagata et al. J Am Coll Cardiol Img 2015;8:235–45

2D Global Longitudinal Strain

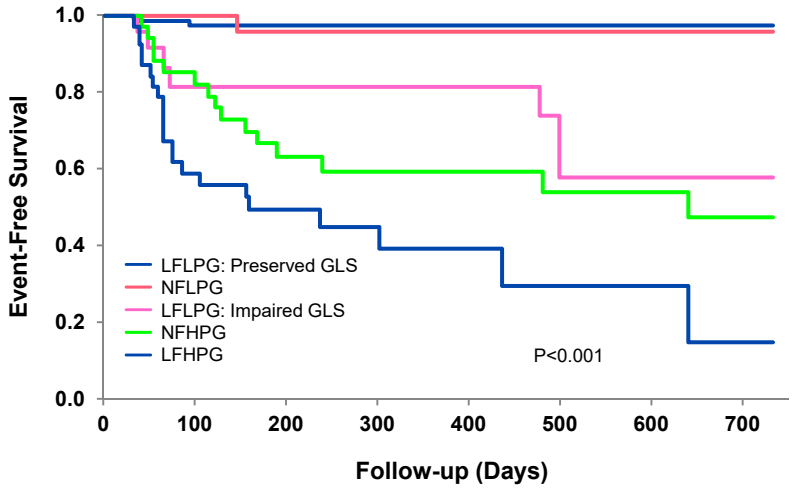
All Cause Mortality



Ng et al. European Heart Journal - Cardiovascular Imaging (2017) 0, 1–9

2D Global Longitudinal Strain

Survival from MACE



Sato et al. Circ J 2014;78:2750-2759

Echocardiographic Evaluation of Aortic Stenosis

Rule #7:

The evaluation of left ventricular function should include not only a measure of ejection fraction but also global longitudinal strain.

Severe Valve Disease
Asymptomatic (Stage C)

LVEF ≥ 50%
LVESD ≤ 50mm
LVEDD ≤ 65mm

LVEF ≥ 50%
Vmax <5m/s
ΔPmean <60mmHg
Normal ETT
ΔVmax ≤0.3m/s/yr

Or Mortality ≥1%

Very Severe MVA≤1cm² $T_{1/2}$ ≥ 220
- Unfavorable morphology,
LA clot, > mild MR
Severe MVA≤1.5cm² $T_{1/2}$ ≥ 150
-Sinus rhythm
-Afib with Unfavorable morphology,
LA clot, > mild MR

Positive Stress Test

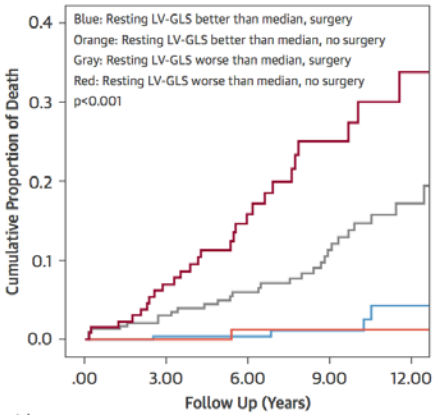
? Rest LV GLS (>) -16%

- Aortic Regurgitation*
- Aortic Stenosis
- Mitral Regurgitation
- Mitral Stenosis

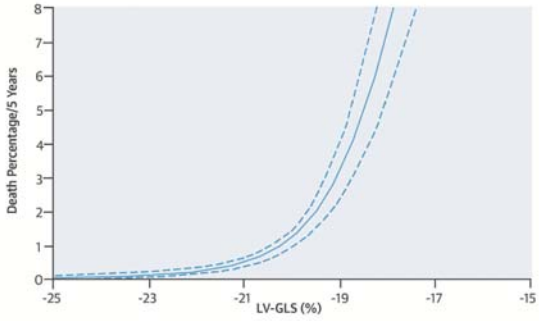
Valve Replacement

*ACC/AHA NOT ESC guidelines

Global Longitudinal Strain and Primary MR
Normal LV Size, LVEF ≥ 60%

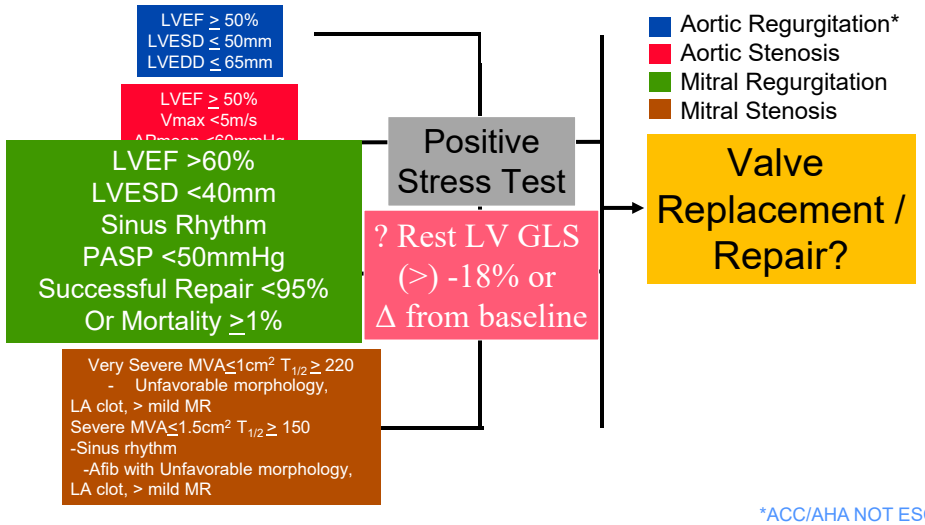


Estimated Risk of Death at 5 years for Resting LV GLS



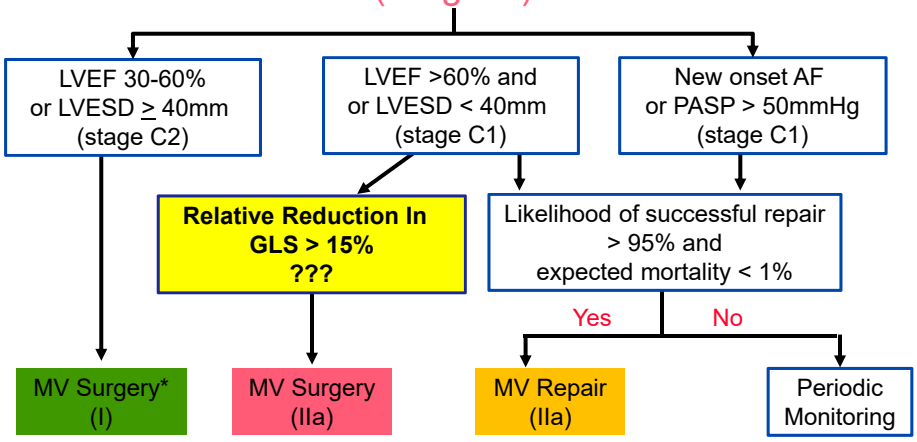
Mentias et al. J Am Coll Cardiol 2016;68:1974–86

Severe Valve Disease
Asymptomatic (Stage C)



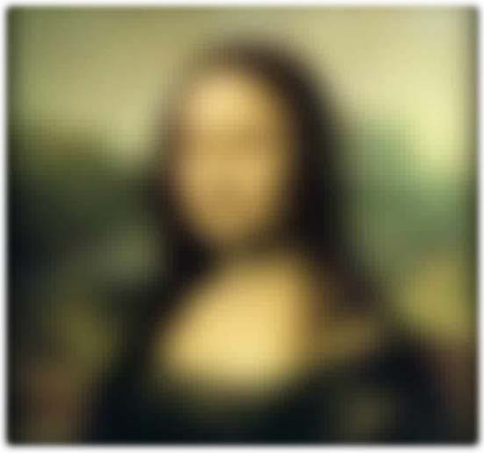
*ACC/AHA NOT ESC guidelines

Indications for Surgery For MR
Primary MR (Stage C)



Nishimura et al: J Am Coll Cardiol; Valve Focused Update, 2017

Myocardial Imaging
Proven Utility & Potential
A Masterpiece in Echocardiography?



1. Subclinical LV dysfunction
2. HCM Phenocopies
3. Valve Disease
4. …
5. …

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